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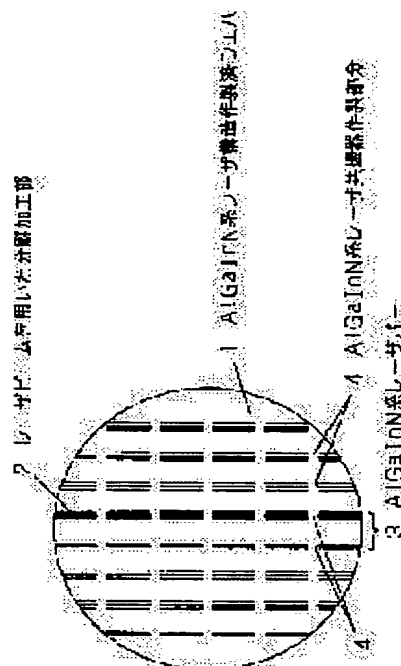
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(54) NITRIDE-BASED SEMICONDUCTOR DEVICE AND MANUFACTURING METHOD

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a manufacturing method of a laser beam resonator having high reproducibility and yields by forming a separation groove where flatness on a section is excellent on an AlGaInN-based crystal substrate.

SOLUTION: In an AlGaInN-based laser wafer manufactured on a sapphire substrate, the substrate is irradiated with a pulse laser beam from the back side, and then is applied to an AlGaInN-based crystal section other than the laser resonator section of a surface for forming a separation groove. After that, force is applied along the separation groove for separating the substrate to a laser bar. In this manner, the surface of the resonator where flatness is extremely high and a reflection loss rarely exists is achieved, thus achieving manufacture with high reproducibility and yields.



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CLAIMS

[Claim(s)]

[Claim 1] The manufacture approach of the AlGaInN system semiconductor device characterized by having the process which forms a separation slot by irradiating pulse laser beam light at least at either among the crystal section of the AlxGayInzN ($x+y+z=1$) system crystal constituted on the substrate, and the substrate section.

[Claim 2] The manufacture approach of the AlGaInN system semiconductor device characterized by having the process which performs isolation by irradiating pulse laser beam light at least at either among the crystal section of the AlxGayInzN ($x+y+z=1$) system crystal constituted on the substrate, and the substrate section.

[Claim 3] The manufacture approach of the AlGaInN system semiconductor device according to claim 1 or 2 characterized by the exposure field and the non-irradiating field of pulse laser beam light being periodic.

[Claim 4] The manufacture approach of the AlGaInN system semiconductor device according to claim 3 characterized by a pulse laser beam *** exposure field including the resonator side formation field of a laser diode.

[Claim 5] The manufacture approach of the AlGaInN system semiconductor device characterized by including the process which forms a separation slot in the crystal section and the rear face substrate section of an AlxGayInzN ($x+y+z=1$) system crystal which were constituted on the substrate, and the process which irradiates pulse laser beam light in either at least among said separation slots, and carries out additional processing of said separation slot.

[Claim 6] The manufacture approach of the AlGaInN system semi-conductor light emitting device characterized by having the process which accompanies the separation slot formed according to the process including the process which irradiates pulse laser beam light, and produces the resonator side of a laser diode by carrying out a cleavage.

[Claim 7] The manufacture approach of the AlGaInN system semi-conductor light emitting device characterized by having the process which produces the resonator side of a laser diode by irradiating pulse laser beam light.

[Claim 8] It is the manufacture approach of an AlGaInN system semiconductor device given in any 1 term among claims 1-7 characterized by basing the separation slot formation approach by pulse laser beam light exposure on multiple photon process.

[Claim 9] The manufacture approach of an AlGaInN system semiconductor device given in either of claims 1-8 characterized by a substrate being sapphire.

[Claim 10] The manufacture approach of the AlGaInN system semiconductor device characterized by having the process which performs recessing to at least one side among a substrate front face or a rear face, and the process which produces an AlGaInN system semiconductor device on said substrate.

[Claim 11] The manufacture approach of the AlGaInN system semiconductor device according to claim 10 characterized by modulating the period of recessing in a substrate.

[Claim 12] The manufacture approach of the AlGaInN system semiconductor device according to claim 10 or 11 characterized by modulating the processing depth of flute in a substrate.

[Claim 13] The AlGaInN system semiconductor device characterized by having the substrate which performed recessing to either [at least] the front face or the rear face.

[Claim 14] The AlGaInN system semiconductor device characterized by the period of recessing becoming irregular in a substrate.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the AlGaInN system semi-conductor light emitting device and the manufacture approaches in wavelength regions, such as blue, green, and red, such as semiconductor laser and light emitting diode, from ultraviolet [from which the application to optical information processing, a display, the lighting field, etc. is expected].

[0002]

[Description of the Prior Art] Promising ** of the III-V nitride semi-conductor which has nitrogen (N) in V group element is carried out as an ingredient of a short wavelength light emitting device from the magnitude of the band gap. Especially, research is done briskly and, as for the gallium nitride system compound semiconductor (GaN system semi-conductor: $\text{Al}_x\text{Ga}_{1-x}\text{In}_y\text{N}$ ($0 < x, y, z < 1, x+y+z=1$)), blue light emitting diode (LED) and green LED are put in practical use. Moreover, the semiconductor laser which has oscillation wavelength on 400nm band is desired for large-capacity-izing of an optical disk unit, semiconductor laser made from a GaN system semi-conductor attracts attention, and practical use level is reached in current.

[0003] Drawing 10 is a structure section Fig. of GaN system semiconductor laser where laser oscillation is attained, the Lord of silicon on sapphire 1001 — C side top — metal-organic chemical vapor deposition (MOVPE law) — the GaN buffer layer 1002, the n-GaN layer 1003, the n-AlGaIn cladding layer 1004, the n-GaN lightguide layer 1005, and $\text{Ga}_{1-x}\text{In}_x\text{N}/\text{Ga}_{1-y}\text{In}_y\text{N}$ ($0 < x < 1$) from — the multiplex quantum well (MQW) barrier layer 1006 which changes, the p-GaN lightguide layer 1007, the p-AlGaIn cladding layer 1008, and the p-GaN contact layer 1009 grow. And a ridge stripe with a width of face of about 10 microns is formed from width of face 3 on the p-GaN contact layer 1009, and the both sides are embedded by SiO_2 1011. The n electrode 1012 which consists of Ti/aluminum is formed in the front face etched until the n-GaN layer 1003 exposed after that the p electrode 1010 which consists of nickel/Au, and the part on a ridge stripe and SiO_2 1011. If the n electrode 1012 is grounded in this component and an electrical potential difference is impressed to the p electrode 1010, the n electrode 1012 side to an electron will be poured in for a hole from the p electrode 1010 side toward the MQW barrier layer 1006 again, optical gain will be produced within said MQW barrier layer 1006, and the laser oscillation of an oscillation wavelength the band of 400nm will be started. Oscillation wavelength changes with the presentations and thickness of a $\text{Ga}_{1-x}\text{In}_x\text{N}/\text{Ga}_{1-y}\text{In}_y\text{N}$ thin film which are the ingredient of the MQW barrier layer 1006. Continuous oscillation beyond a current room temperature is realized.

[0004] By controlling the width of face and the height of a ridge stripe, a device which carries out laser oscillation by the basic mode in the horizontal transverse mode accomplishes this laser. That is, the oscillation by the basic transverse mode is enabled by preparing a difference in the optical confinement factor of the basic transverse mode and the higher mode (primary more than mode).

[0005] After carrying out [grind / the rear face of silicon on sapphire 1001] (for example, after the resonator side of laser puts in the scribe blemish which serves as a guide of separation using a diamond cutter etc.), the cleavage of it is carried out by the Ath page (11-20) (field) of sapphire, and the Mth page (1-100) (field), and the technique of exposing the Ath page of the AlGaInN system crystal which carried out crystal growth by dry etching, or the Mth page is used.

[0006] Moreover, not only laser but in case it produces AlGaInN system light emitting diode (LED), a diamond cutter etc. is used like said approach as the isolation approach, a separation slot is put into a crystal [of a component], or substrate side, or the process of said cutter cutting directly mechanically is performed.

[0007] On the other hand, although sapphire, SiC, NGO, etc. are used for the substrate of an AlGaInN system crystal, it is difficult for any substrate not to carry out lattice matching to GaN, but to obtain coherent growth. consequently, the case where there were many rearrangements (edge dislocation, a screw dislocation, mixed dislocation), for example, they use silicon on sapphire — about 1 — the rearrangement of $\times 10^9\text{cm}^{-2}$ exists. Consequently, the fall of the dependability of semiconductor laser is caused.

[0008] The selection longitudinal direction growth (ELO) using the dielectric mask and the processing substrate as the approach of dislocation density reduction is proposed. This has effective grid mismatching as an approach of reducing a penetration rearrangement, in a large system.

[0009] Drawing 11 expresses typically distribution of the rearrangement of the GaN crystal formed by ELO. drawing 11 (a) — like — first — a silicon-on-sapphire 1101 top — MOVPE — the GaN layer 1102 is deposited by law etc. After depositing SiO_2 1103 in CVD etc., SiO_2 1103 is processed in the shape of [periodic] a stripe by photolithography and etching. The GaN layer 1104 is deposited with selective growth by using as seed crystal the part which GaN 1102 exposed. as the growth approach — MOVPE — law and HVPE — law is used. Although the field 1106 with many abbreviation $\times 10^9\text{cm}^{-2}$ and the rearrangement in the upper part of seed crystal exists, dislocation density can be reducing the part which carried out longitudinal direction growth to about [$\times 10^7\text{cm}^{-2}$] two. It becomes possible to raise dependability by forming an active region, i.e., a current impregnation field, in the upper part of the field 1105 with few this rearrangement. Moreover, like drawing 11 (b), level difference processing is performed to silicon on sapphire 1107 in the shape of [periodic] a stripe by dry etching etc., and longitudinal direction growth of the GaN layer 1108 is carried out after that. The field 1110 with few rearrangements is formed on the opening 1109 produced in longitudinal direction growth. It becomes possible to raise

dependability by forming an active region, i.e., a current impregnation field, in the upper part of the field 1110 with few this rearrangement.

[0010] When selection longitudinal direction growth is used, a laser cavity exposes the Ath page of an AlGaInN system crystal, or the Mth page for a substrate using a cleavage or dry etching.

[0011]

[Problem(s) to be Solved by the Invention] however, by the formation approach of the above-mentioned laser cavity For example, when the cleavage approach is used and an AlGaInN system crystal is grown up on the sapphire C side 51, as shown in drawing 5 (a), Mth page 51 and the Mth page of an AlGaInN system crystal of sapphire, since 52 [30-degree] shifts and its 53 corresponds the Mth page of sapphire, and the Ath page of an AlGaInN system crystal, if the cleavage of the silicon on sapphire is carried out, the field shifted 30 degrees will be mixed at random, and the irregularity of several 100nm will enter. If such irregularity goes into a resonator side, the mirror loss of a laser beam will increase and increase of the operating current of semiconductor laser, as a result the fall of dependability will be brought about. Furthermore, in order that the irregularity in said resonator side may enter at random, it is difficult to produce a resonator side with a fixed reflection factor with sufficient repeatability, and that the yield becomes low poses a problem.

[0012] Even if it uses dry etching as the formation approach of a resonator, the same trouble occurs.

[0013] Moreover, as shown in drawing 5 (b), when the separation slot 56 is formed using a diamond cutter, a crack and a blemish 57 go into a slot periphery. If this blemish goes into a part for the AlGaInN system laser resonance vessel part 58, a laser oscillation property will be reduced remarkably. Since a micro, further more small defect is also generated by the luminescence field of AlGaInN system laser, the dependability of laser also falls remarkably. Therefore, it is necessary to keep away the separation slot 56 from a part for the AlGaInN system laser resonance vessel part 58 as much as possible, and to shorten a separation slot as a result by this approach. however, the time of producing the AlGaInN system laser bar 57 according to a cleavage, since the crystal face of silicon on sapphire and an AlGaInN system crystal is not in agreement as said drawing 5 (a) explained if a separation slot is short — from the both ends of a substrate — linear — a cleavage — it cannot do — on the way — coming out — from a separation slot — swerving — low — only a yield cleavage is made.

[0014] Moreover, if the AlGaInN system laser structure 72 is grown up using the mask substrate and level difference processing substrate which performed silicon on sapphire or periodic processing as shown in drawing 7 (a), it originates in the grid mismatching and thermal-expansion mismatching between a substrate and an AlGaInN system crystal, and the problem that the whole EPI substrate will curve after AlGaInN system crystal growth occurs. In a laser production process, in order to become a serious failure at the alignment at the time of producing the ridge stripe for a current constriction and to acquire a resonator side by the final process, when carrying out the cleavage of the curvature of a substrate, it does not break linearly but causes a low yield.

[0015] This invention is made in view of the above-mentioned situation, and offers the approach of producing a reliable nitride semiconductor device with the sufficient yield. In the application to the laser for optical disks, it is especially effective.

[0016]

[Means for Solving the Problem] The first manufacture approach of the AlGaInN system semi-conductor of this invention is characterized by forming a separation slot by irradiating pulse laser beam light at least at either among the crystal section of the $\text{Al}_x\text{Ga}_y\text{In}_z\text{N}$ ($x+y+z=1$) system crystal constituted on substrates, such as sapphire, and the substrate section.

[0017] Moreover, the second manufacture approach of the AlGaInN system semi-conductor of this invention is characterized by performing isolation by irradiating pulse laser beam light at least at either among the crystal section of the $\text{Al}_x\text{Ga}_y\text{In}_z\text{N}$ ($x+y+z=1$) system crystal constituted on the substrate, and the substrate section. Especially, the exposure field and the non-irradiating field of pulse laser beam light are periodic, and it is characterized by a pulse laser beam **** exposure field including the resonator side formation field of a laser diode.

[0018] moreover , the third manufacture approach of the AlGaInN system semi-conductor of this invention be characterize by irradiate pulse laser beam light in either at least among said separation slots , and carry out additional processing of said separation slot to the process which form a separation slot in the crystal section and the rear face substrate section of an $\text{Al}_x\text{Ga}_y\text{In}_z\text{N}$ ($x+y+z=1$) system crystal which be constituted on the substrate . It is characterized by producing the resonator side of a laser diode directly by accompanying the separation slot formed according to the process including the process which irradiates pulse laser beam light especially, and irradiating production or pulse laser beam light to the resonator side of a laser diode by carrying out a cleavage. It is characterized by the manufacture approach of said AlGaInN system semi-conductor depending the separation slot formation approach by pulse laser beam light exposure on multiple photon process.

[0019] Moreover, it is characterized by the fourth manufacture approach of the AlGaInN system semi-conductor of this invention and component structure having the process which performs recessing to at least one side among a substrate front face or a rear face, and the process which produces an AlGaInN system semiconductor device on said substrate, and is characterized by modulating either [at least] the period of a processing slot, or the depth in a substrate especially.

[0020]

[Embodiment of the Invention] Hereafter, the gestalt of operation of this invention is explained to a detail using a drawing. the growth approach of the AlGaInN system semi-conductor of this invention — MOVPE — it does not limit to law, and hydride vapor growth (HVPE law), a molecular beam epitaxy method (MBE law), etc. are applicable to all the approaches proposed until now, in order to grow up an AlGaInN system nitride semi-conductor layer.

[0021] (Example 1) a component sectional view is shown in drawing 6 — as — first — MOVPE — law — the Lord of silicon on sapphire 601 — C side top — the GaN buffer layer 602, the n-AlGaIn layer 603, the n-AlGaIn cladding layer 604, the n-GaN lightguide layer 605, and Ga $1-x$ In x N/Ga $1-y$ In y N ($0<y<x<1$) from — crystal growth of the multiplex quantum well (MQW) barrier layer 606 which changes, the p-GaN lightguide layer 607, the p-AlGaIn cladding layer 608, and the p-GaN contact layer 609 is carried out. And a ridge stripe with a width of face of about 3 micrometers is formed on the p-GaN contact layer 609, and the both sides are embedded by SiO 2 611. The n electrode 612 which consists of Ti/aluminum is formed in the front face etched until the n-AlGaIn layer 603 exposed after that the p electrode 610 which consists of nickel/Au, and the part on a ridge stripe and SiO 2 611. If the n electrode 612 is grounded in this component and an electrical potential

difference is impressed to the p electrode 610, the n electrode 612 side to an electron will be poured in for a hole from the p electrode 610 side toward the MQW barrier layer 606 again, optical gain will be produced within said MQW barrier layer 606, and the laser oscillation of an oscillation wavelength the band of 400nm will be started.

[0022] Next, as the process sectional view of component production is shown in drawing 2 (a), a diamond cutter etc. is used, scribing is performed and the separation slot 23 is periodically formed in the rear-face side of silicon on sapphire 22. Spacing (period) of said separation slot 23 is about 700 micrometers of the optical-resonator length of a laser diode, and forms a slot in a straight line from the edge of a substrate to an edge. Moreover, the depth of said separation slot 23 is produced to thickness within the limits of silicon on sapphire. In addition, after forming said component structure, the thickness of silicon on sapphire grinds a substrate rear face so that it may become about [total 100micrometer] thickness using a grinding machine. Next, as shown in drawing 2 (b), a pulse laser beam 24 is irradiated from the AlGaInN system laser structure crystal 21 side in the location corresponding to said separation slot 23, and a substrate is separated completely. However, after it is not necessary to make it penetrate to the direct separation slot 23 and it irradiates only the AlGaInN system laser structure crystal 21, a laser beam exposure applies the force to a substrate, may accompany the separation slot 23 and may break it. Moreover, even if the scan of a pulse laser beam moves a condenser lens and moves a beam, it may fix a beam, may hold a substrate on a stage etc., and may move this. Drawing 1 is drawing (drawing seen from the side which gave AlGaInN system crystal growth) showing the condition of having irradiated the pulse laser beam and having formed the separation processing section 2 on the substrate 1 in which the AlGaInN system semiconductor laser structure laser cavity production part, as shown in said drawing 1, but to form the part of an exposure / not irradiating, with the period of component width-of-face extent. If this accompanies the separation processing section 2 and the force is apply in case it produces the AlGaInN system laser bar 3, as the process of said drawing 2 explained, since about four resonator production part which is not irradiating laser can accompany the separation processing section 2, and it can be break easily and influence of laser radiation, it can realize the resonator side by which natural formation was carried out to atomic layer order. In addition, although the direction of the slot which irradiates a laser beam and forms it in drawing 1 is the <11-20> direction of the sapphire which is a substrate, you may be the <1-100> direction. Furthermore, it is satisfactory even if it goes laser radiation for arbitration to a crystal orientation. Drawing 4 is a sectional view [/ near the resonator of the component formed by pulse laser beam exposure using said approach]. Laser radiation is performed in the <11-20> direction of sapphire. Since 43 is formed with a sufficient precision the Mth page of sapphire, the surface smoothness of the resonator side 41 (Ath page in this case) of AlGaInN system laser is formed with very good and sufficient repeatability.

[0023] In this invention, the peak wavelength of for example, a titanium sapphire system of the pulse laser to irradiate is near infrared rays, and pulse width uses the ultrashort pulse of several 100 fs(es). The cusp value power of the laser irradiated by using ultrashort pulse laser can be increased remarkably for a short time, according to a multiple-photon-absorption process, atomic association goes out and separation cutting of a substrate or the crystal is carried out by the strong laser power obtained for a short time (laser ablation). It becomes possible to reduce the damage by heat remarkably in the field which irradiated the laser beam by this.

[0024] Furthermore, in this invention, even if it irradiates till just before (about several micrometers) near the resonator of the laser component produced by irradiating a pulse laser beam, recessing can be carried out, without giving a damage to said resonator. When recessing is conventionally carried out using a diamond cutter etc., recessing can be carried out only to the location which separated about 100 micrometers from the resonator of the laser component produced in order that a check and a defect may go into a slot periphery. For this reason, although the slot used as sufficient guide was not obtained when producing a laser bar, but it separated greatly [in case the force is applied and broken] on the way and the yield was reduced extremely, the marked improvement in the yield was realizable with this invention.

[0025] In addition, although sapphire was shown as a substrate in this example, it is effective also about other Si and SiC which are generally used for the epitaxial growth of an AlGaInN system crystal, Mg2O3, GaN, and glass, and in the AlGaInN system substrate of a low defect which performed selection longitudinal direction growth using a mask further, it is not effective also until it says.

[0026] (Example 2) The process which irradiates a pulse laser beam at the rear face of a substrate next is explained. The light source used for component structure, substrate thickness, and a pulse laser beam exposure is the same as an example 1.

[0027] The process which irradiates a pulse laser beam at the rear face of a substrate at drawing 3, and carries out separation cutting of the base is shown. As shown in drawing 3 (a), the pulse laser beam exposure 33 is performed and the separation slot 34 is periodically formed in the rear-face side of silicon on sapphire 32. Spacing (period) of said separation slot 34 is about 700 micrometers of the optical-resonator length of a laser diode, and forms a slot in a straight line from the edge of a substrate to an edge. Moreover, the depth of said separation slot 34 is produced to thickness within the limits of silicon on sapphire. At this time, it is in the thickness direction of a substrate, and a part (about 10-20 micrometers) adjusts the focus of a laser beam, and a substrate is made not to be processed by pulse laser light. Next, as shown in drawing 3 (b), a pulse laser beam 35 is irradiated from the AlGaInN system laser structure crystal 31 side in the location corresponding to said separation slot 34, and the separation slot 36 is formed. The pattern of the pulse laser beam exposure 35 shall be periodically performed, without irradiating the resonator edge surface part of the laser component to produce as shown in drawing 1 like an example 1. Finally, as shown in drawing 3 (c), the force is applied to the condition of drawing 3 (b), and a substrate is broken.

[0028] since a pulse laser beam is irradiated from a substrate rear face side according to the process of this invention -- the substrate thickness direction -- setting -- until [of an AlGaInN system laser structure crystal and a substrate] last-minute near the interface -- since recessing can be carried out without giving a damage to said crystal section, in order to avoid the crack and the crack produced around the recessing section like [at the time of using a diamond cutter etc.], it is not necessary to separate recessing from the interface of a crystal and a substrate, and it is markedly alike, and a laser bar can produce with the sufficient yield.

[0029] Even if this invention uses for substrates other than sapphire, the effective thing is the same as that of an example 1.

[0030] (Example 3) As shown in drawing 8 (a), photolithography, a dry etching process, etc. are used for the sapphire C side substrate 81, and recessing 82 is performed. The thickness and the diameters of all of the used substrate are about 400 micrometers and 2 inches, respectively. Recessing is performed on a straight line along $\langle 1-100 \rangle$ and the $\langle 11-20 \rangle$ direction of sapphire, and a substrate periphery makes spacing of a slot and a slot dense. spacing of a typical slot and a typical slot — for a substrate core, about 500–1000 micrometers and a substrate periphery is [the channel depth of a flute width] about about 5–100 micrometers in about 1–3 micrometers at about 50–100 micrometers. In addition, recessing may produce by performing a pulse laser beam exposure.

[0031] The AlGaInN system laser structure which shows a sectional view in drawing 9 using said processing substrate is produced. A GaN buffer layer is minded [who has the opening 902 which performed recessing first shown in said drawing 8 (a) by the MOVPE method / of silicon on sapphire 901] on C side. the undoping GaN layer 903, the n-GaN layer 904, the n-AlGaIn cladding layer 905, the n-GaN lightguide layer 906, and Ga_{1-x}In_xN/Ga_{1-y}In_yN ($0 < x < 1$) from — the multiplex quantum well (MQW) barrier layer 907 which changes — Crystal growth of the p-AlGaIn/GaN superlattice cap layer 908, the p-GaN lightguide layer 909, the p-AlGaIn/GaN superlattice cladding layer 910, the second contact layer 911 of p-GaN, and the second contact layer 912 of p-GaN is carried out one by one. And a ridge stripe with a width of face of about 3 micrometers is formed on the second contact layer 912 of p-GaN, and the both sides are embedded by SiO₂914. The n electrode 915 which consists of Ti/aluminum is formed in the front face etched until the n-GaN layer 904 exposed after that the p electrode 913 which consists of nickel/Au, and the part on a ridge stripe and SiO₂914. If the n electrode 915 is grounded in this component and an electrical potential difference is impressed to the p electrode 913, the n electrode 915 side to an electron will be poured in for a hole from the p electrode 913 side toward the MQW barrier layer 907 again, optical gain will be produced within said MQW barrier layer 907, and the laser oscillation of an oscillation wavelength the band of 400nm will be started.

[0032] When crystal growth of said component structure is carried out using the silicon on sapphire which performed recessing with a modulation period as shown in drawing 8 (a), very big effectiveness is to reduce the curvature and crack of a substrate, as shown below. That is, as shown in drawing 7 R> 7 (b), on the opening 76 given to silicon on sapphire 74, the AlGaInN system laser structure 75 carries out longitudinal direction growth, and since it joins together smoothly by the bond part 74, the crystal surface smoothness on the front face of a component is secured. Furthermore, in a substrate periphery, the processing period of recessing is shorter than a substrate core, since an opening exists more densely, the stress produced between silicon on sapphire 74 and the AlGaInN system laser structure 75 in this field is eased, and the crack of the crystal section brought about by curvature, deformation, and also these is reduced remarkably. Consequently, since the location gap with a photo mask etc. was lost when carrying out crystal growth of said component structure using the substrate of a 2 inch system, using photolithography etc. for this and forming the ridge stripe of laser, when mass-producing, it turned out that it can produce with the very sufficient yield. Furthermore, as shown in an example 1 or an example 2, when producing a laser bar, even if it was, when the curvature of a substrate and deformation were abolished using this invention, it became clear that a laser bar was remarkably producible by the high yield.

[0033] Concentric circular [with which the perimeter of a substrate was more densely got blocked as shown in drawing 8 (b)] is sufficient as recessing of silicon on sapphire. In this case, deformation by distortion can be controlled more over the whole substrate. Furthermore, if recessing is performed only along a specific direction as shown in $\langle 1-100 \rangle$ and $\langle 11-20 \rangle$ as shown in drawing 8 (c) for example, since distortion of a direction perpendicular to recessing is eased rather than a parallel distortion, it is realizable to apply different direction distortion stress intentionally in the c-th page, by distortion, the band structure of an AlGaInN system crystal will be changed and the luminescence property improvement of laser will be attained.

[0034] Moreover, since a substrate periphery is eased more when a substrate periphery makes the depth of recessing deep, said depth modulation is effective to the curvature of a substrate, or deformation like the case of a periodic modulation.

[0035]

[Effect of the Invention] As explained above, according to the first manufacture approach of the AlGaInN system semi-conductor of this invention By irradiating pulse laser beam light and forming a separation slot in either at least, among the crystal section of the Al_xGa_yIn_zN ($x+y+z=1$) system crystal constituted on the substrate, and the substrate section It is possible to produce the separation slot cross section which could realize recessing faithfully along the crystal face of said substrate and an AlGaInN system crystal, and was extremely excellent in surface smoothness.

[0036] Moreover, according to the second manufacture approach of the AlGaInN system semi-conductor of this invention By performing isolation by irradiating pulse laser beam light at least at either among the crystal section of the Al_xGa_yIn_zN ($x+y+z=1$) system crystal constituted on the substrate, and the substrate section the case where isolation became faithful ** possible in the crystal face of said substrate and an AlGaInN system crystal, and this process is applied to semiconductor laser — very — high — it becomes producible [a yield laser diode optical-resonator end face].

[0037] Moreover, according to the third manufacture approach of the AlGaInN system semi-conductor of this invention The process which forms a separation slot in the crystal section and the rear-face substrate section of an Al_xGa_yIn_zN ($x+y+z=1$) system crystal which were constituted on the substrate, Production of a very flat laser diode resonator side becomes possible at the high yield by irradiating pulse laser beam light in either at least among said separation slots, carrying out additional processing of said separation slot, accompanying the separation slot irradiated and formed and carrying out the cleavage of the pulse laser beam light. Especially the separation slot formation approach by said pulse laser beam light exposure is not based on multiple photon process, and is not dominant, and since association of the atom which constitutes a crystal for a short time can be cut without damaging the substrate and crystal which constitute a laser diode, the light emitting device excellent in dependability is realizable. [of a thermal process]

[0038] Moreover, according to the fourth manufacture approach of the AlGaInN system semi-conductor of this invention, and component structure After performing recessing which made at least one side modulate a period or the depth in a substrate among a substrate-front face or a rear face, by producing an AlGaInN system semiconductor device on said substrate Heat distortion generated between the substrate which constitutes a component, and said AlGaInN system crystal can be reduced, and a quality component without curvature, deformation, a crack, etc. can be realized.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] Drawing showing the separation slot formation pattern by the pulse laser beam exposure on the substrate in which AlGaInN system component structure was formed

[Drawing 2] (a) Process drawing of the separation slot formation by pulse laser beam exposure

(b) Process drawing of the separation slot formation by pulse laser beam exposure

[Drawing 3] (a) Process drawing of the separation slot formation by pulse laser beam exposure

(b) Process drawing of the separation slot formation by pulse laser beam exposure

(c) Process drawing of the separation slot formation by pulse laser beam exposure

[Drawing 4] The component sectional view formed by pulse laser beam exposure

[Drawing 5] (a) The component sectional view formed by the conventional scribing method

(b) Drawing showing the separation slot formation pattern formed by the conventional scribing method

[Drawing 6] Drawing showing the AlGaInN system component structure where the process of this invention was given

[Drawing 7] (a) The silicon-on-sapphire top AlGaInN system component sectional view by the conventional method

(b) The silicon-on-sapphire top AlGaInN system component sectional view by this invention

[Drawing 8] (a) Drawing showing the processing pattern to the substrate top by this invention

(b) Drawing showing the processing pattern to the substrate top by this invention

(c) Drawing showing the processing pattern to the substrate top by this invention

[Drawing 9] The AlGaInN system component sectional view using the processing substrate by this invention

[Drawing 10] The AlGaInN system component sectional view using the processing substrate by the conventional method

[Drawing 11] (a) The structure section Fig. of the GaN crystal using the mask substrate by the conventional method

(b) The structure section Fig. of the GaN crystal using the processing substrate by the conventional method

[Description of Notations]

1 Wafer Produced [AlGaInN System Laser Structure]

2 Separation Processing Section Using Laser Beam

3 AlGaInN System Laser Bar

4 AlGaInN System Laser Cavity Production Part

21 AlGaInN System Laser Structure

22 Silicon on Sapphire

23 Separation Slot

24 Pulse Laser Beam Exposure

25 Separation Slot

31 AlGaInN System Laser Structure

32 Silicon on Sapphire

33 Pulse Laser Beam Exposure

34 Separation Slot

35 Pulse Laser Beam Exposure

36 Separation Slot

41 AlGaInN System Laser Cavity Side

42 Sapphire C Side

43 Mth Page of Sapphire

51 Mth Page of Sapphire

52 Mth Page of AlGaInN System Laser Crystal

53 Ath Page of AlGaInN System Laser Crystal

54 Sapphire C Side

55 Wafer Produced [AlGaInN System Laser Structure]

56 Separation Slot Using Diamond Cutter

57 Crack and Blemish of Separation Slot Periphery

58 Laser Cavity Production Part

71 Silicon on Sapphire

72 AlGaInN System Laser Structure

73 Field Where Deformation and Stress are Large

74 Bond Part

75 AlGaInN System Laser Structure

76 Opening

81 Silicon on Sapphire

82 Recessing

83 Silicon on Sapphire

84 Recessing

85 Silicon on Sapphire
86 Recessing
601 Silicon on Sapphire
602 Buffer Layer
603 N-AlGaIn Layer
604 N-AlGaIn Cladding Layer
605 N-GaN Lightguide Layer
606 GaInN/GaN-MQW Barrier Layer
607 P-GaN Lightguide Layer
608 P-AlGaIn Cladding Layer
609 P-GaN Contact Layer
610 P Electrode
611 SiO₂
612 N Electrode
901 Silicon on Sapphire
902 Opening
903 U-GaN Layer
904 N-GaN Layer
905 N-AlGaIn Cladding Layer
906 N-GaN Lightguide Layer
907 Barrier Layer
908 P-AlGaIn/GaN Superlattice Cap Layer
909 P-GaN Lightguide Layer
910 P-AlGaIn/GaN Superlattice Cladding Layer
911 Second Contact Layer of P-GaN
912 First Contact Layer of P-GaN
913 P Electrode
914 SiO₂
915 N Electrode
1001 Silicon on Sapphire
1002 Buffer Layer
1003 N-AlGaIn Layer
1004 N-AlGaIn Cladding Layer
1005 N-GaN Lightguide Layer
1006 GaInN/GaN-MQW Barrier Layer
1007 P-GaN Lightguide Layer
1008 P-AlGaIn Cladding Layer
1009 P-GaN Contact Layer
1010 P Electrode
1011 SiO₂
1012 N Electrode
1101 Silicon on Sapphire
1102 GaN
1103 SiO₂
1104 GaN Layer
1105 Field with Few Rearrangements
1106 Field with Many Rearrangements
1107 Silicon on Sapphire
1108 GaN
1109 Opening
1110 Field with Few Rearrangements
1111 Field with Many Rearrangements

[Translation done.]

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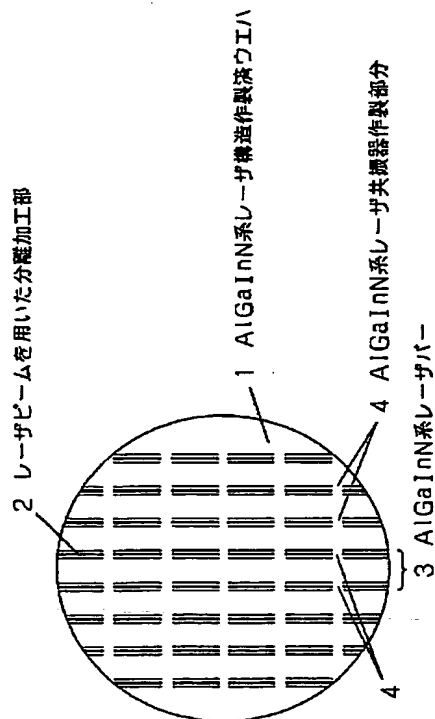
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(54) 【発明の名称】 窒化物系半導体素子及び製造方法

(57) 【要約】

【課題】 A l G a I n N系結晶基板において断面の平坦性に優れた分離溝を形成し、再現性が高くかつ高歩留まりなレーザ光共振器作製方法を提供する。

【解決手段】 サファイア基板上に作製したA l G a I n N系レーザウエハにおいて、パルスレーザビームを基板裏面から照射した後、表面のレーザ共振器部分を除くA l G a I n N系結晶部に照射して分離溝を形成する。この後、前記分離溝に添って力を加え基板をレーザバーに分離する。この方法によりレーザ結晶部にダメージを与えることなく極めて平坦性が高く反射ロスのほとんど無い共振器面が実現でき、かつ再現性が高く高歩留まりな作製が可能となる。



を制御することによって、水平方向の横モードにおいて基本モードでレーザ発振するような工夫が成される。すなわち、基本横モードと高次モード（1次以上のモード）の光閉じ込め係数に差を設けることで、基本横モードでの発振を可能としている。

【0005】レーザの共振器面はサファイア基板1001の裏面を研磨する等した後、例えばダイヤモンドカッター等を用いて分離のガイドとなるスクライブ傷を入れた後サファイアA面（11-20）面またはM面（1-100）面でへき開したり、またドライエッチングにより結晶成長したAlGaInN系結晶のA面またはM面を露出させる等の手法が用いられている。

【0006】またレーザに限らず、AlGaInN系発光ダイオード（LED）を作製する際にも素子分離方法として前記方法のようにダイヤモンドカッター等を用いて素子の結晶または基板側に分離溝を入れたり、前記カッターで直接機械的に切断する等の工程が行われている。

【0007】他方、AlGaInN系結晶の基板には、サファイア、SiC、NGOなどが用いられるが、いずれの基板もGaNと格子整合せず、コヒーレント成長を得ることが難しい。その結果、転位（刃状転位、らせん転位、混合転位）が多く、例えばサファイア基板を用いた場合、約 $1 \times 10^9 \text{ cm}^{-2}$ の転位が存在する。その結果、半導体レーザの信頼性の低下を引き起こす。

【0008】転位密度低減の方法として誘電体マスクや加工基板を用いた選択横方向成長（ELO）が提案されている。これは格子不整合が大きい系において、貫通転位を低減させる方法として有効である。

【0009】図11はELOによって形成したGaN結晶の転位の分布を模式的に表したものである。図11

(a)のように、まず、サファイア基板1101上にMOVPE法などによりGaN層1102を堆積する。SiO₂1103をCVDなどで堆積した後、フォトリソグラフィとエッチングによって周期的なストライプ状にSiO₂1103を加工する。GaN1102の露出した部分を種結晶として選択成長によってGaN層1104を堆積する。成長方法としてMOVPE法やHVP E法を用いる。種結晶の上部は約 $1 \times 10^9 \text{ cm}^{-2}$ と転位の多い領域1106が存在するが、横方向成長した部分は転位密度が $1 \times 10^7 \text{ cm}^{-2}$ 程度まで低減できている。この転位の少ない領域1105の上部に活性領域、つまり電流注入領域を形成することで信頼性を向上させることが可能となる。また、図11(b)のように、サファイア基板1107にドライエッチングなどにより周期的なストライプ状に段差加工を施し、その後GaN層1108を横方向成長させる。横方向成長で生じた空隙1109上には転位の少ない領域1110が形成される。この転位の少ない領域1110の上部に活性領域、つまり電流注入領域を形成することで信頼性を向上させ

ることが可能となる。

【0010】選択横方向成長を用いた場合においてもレーザ共振器は基板をへき開またはドライエッチングを用いてAlGaInN系結晶のA面またはM面を露出させる。

【0011】

【発明が解決しようとする課題】ところが、上記レーザ共振器の形成方法では、例えばへき開方法を用いた場合、図5(a)に示すようにサファイアC面51上にAlGaInN系結晶を成長した場合、サファイアM面51とAlGaInN系結晶M面52は30°ずれ、サファイアM面とAlGaInN系結晶A面53が一致するためにサファイア基板をへき開すると30°ずれた面がランダムに混じり数100nmの凹凸が入ってしまう。共振器面にこのような凹凸が入るとレーザ光のミラー損失が増大し、半導体レーザの動作電流の増大、ひいては信頼性の低下をもたらす。更に、前記共振器面での凹凸はランダムに入るために、一定の反射率を有した共振器面を再現性良く作製することは困難であり、歩留まりが低くなることが問題となる。

【0012】共振器の形成方法としてドライエッチングを用いても同様の問題点が発生する。

【0013】また、図5(b)に示すようにダイヤモンドカッターを用いて分離溝56を形成した場合、溝周辺部にひび割れや傷57が入る。この傷がAlGaInN系レーザ共振器部分58に入れば、レーザ発振特性を著しく低下させる。さらにより小さなマイクロな欠陥もAlGaInN系レーザの発光領域に生成されるので、レーザの信頼性も著しく低下する。従ってこの方法では分離溝56をAlGaInN系レーザ共振器部分58からできるだけ遠ざけ、結果的に分離溝を短くする必要がある。しかしながら分離溝が短いと前記図5(a)で説明したようにサファイア基板とAlGaInN系結晶の結晶面が一致していないために、AlGaInN系レーザバー57をへき開により作製する際に基板の両端から直線的にへき開できず途中で分離溝からそれてしまい低歩留まりなへき開しかできない。

【0014】また、図7(a)に示すようにサファイア基板あるいは周期的な加工を施したマスク基板や段差加工基板を用いてAlGaInN系レーザ構造72を成長すると基板とAlGaInN系結晶との間の格子不整合及び熱膨張不整合に起因して、AlGaInN系結晶の成長後にエピ基板全体が反ってしまうという問題が発生する。基板の反りはレーザ作製プロセスにおいて、例えば電流狭窄のためのリッジストライプを作製する際の位置合わせに大きな障害となったり、また最終工程で共振器面を得るためにへき開する場合に直線的に割れず低歩留まりの原因となる。

【0015】本発明は上記の事情を鑑みてなされたものであり、信頼性の高い窒化物半導体素子を歩留まり良く

作製する方法を提供するものである。特に光ディスク用レーザへの応用において効果的である。

【0016】

【課題を解決するための手段】本発明のAlGaInN系半導体の第一の製造方法は、サファイア等の基板上に構成された $Al_xGa_yIn_zN$ ($x+y+z=1$)系結晶の結晶部及び基板部の内少なくともいずれかにパルスレーザビーム光を照射することにより分離溝を形成することを特徴とする。

【0017】また、本発明のAlGaInN系半導体の第二の製造方法は、基板の上に構成された $Al_xGa_yIn_zN$ ($x+y+z=1$)系結晶の結晶部及び基板部の内少なくともいずれかにパルスレーザビーム光を照射することにより素子分離を行うことを特徴とする。特に、パルスレーザビーム光の照射領域と非照射領域が周期的であり、パルスレーザビーム光非照射領域がレーザダイオードの共振器面形成領域を含むことを特徴とする。

【0018】また、本発明のAlGaInN系半導体の第三の製造方法は、基板の上に構成された $Al_xGa_yIn_zN$ ($x+y+z=1$)系結晶の結晶部及び裏面基板部に分離溝を形成する工程と、前記分離溝の内少なくともいずれかにおいてパルスレーザビーム光を照射して前記分離溝を追加加工することを特徴とする。特に、パルスレーザビーム光を照射する工程を含む工程により形成した分離溝に添ってへき開することによりレーザダイオードの共振器面を作製またはパルスレーザビーム光を照射することによりレーザダイオードの共振器面を直接作製することを特徴とする。前記AlGaInN系半導体の製造方法はパルスレーザビーム光照射による分離溝形成方法は多光子過程によることを特徴とする。

【0019】また、本発明のAlGaInN系半導体の第四の製造方法及び素子構造は基板表面または裏面のうち少なくとも一方に溝加工を施す工程と前記基板の上にAlGaInN系半導体素子の作製を行う工程とを有することを特徴とし、特に加工溝の周期または深さの少なくとも一方を基板内において変調させることを特徴とする。

【0020】

【発明の実施の形態】以下、本発明の実施の形態について図面を用いて詳細に説明する。本発明のAlGaInN系半導体の成長方法は、MOVPE法に限定するものではなく、ハイドライド気相成長法(HVPE法)や分子線エピタキシー法(MBE法)など、AlGaInN系窒化物半導体層を成長させるためにこれまで提案されている全ての方法に適用できる。

【0021】(実施例1) 図6に素子断面図を示すように、まずMOVPE法によりサファイア基板601の主面にC面上にGa_{0.9}Nバッファ層602、n-AlGa_{0.9}N層603、n-AlGa_{0.9}Nクラッド層604、n-Ga_{0.9}N光ガイド層605、Ga_{1-x}In_xN/Ga_{1-y}In_yN

($0 < y < x < 1$)から成る多重量子井戸(MQW)活性層606、p-GaN光ガイド層607、p-AlGa_{0.9}Nクラッド層608、p-GaNコンタクト層609を結晶成長する。そしてp-GaNコンタクト層609上に幅3μm程度のリッジストライプが形成され、その両側はSiO₂611によって埋め込まれる。その後リッジストライプおよびSiO₂611上に例えばNi/Auから成るp電極610、また一部をn-AlGa_{0.9}N層603が露出するまでエッチングした表面に例えばTi/Alから成るn電極612が形成される。本素子においてn電極612を接地し、p電極610に電圧を印加すると、MQW活性層606に向かってp電極610側からホールが、またn電極612側から電子が注入され、前記MQW活性層606内で光学利得を生じ、発振波長400nm帯のレーザ発振を起こす。

【0022】次に、図2(a)に素子作製の工程断面図を示すように、サファイア基板22の裏面側にダイヤモンドカッター等を用いてスクライビングを行い分離溝23を周期的に形成する。前記分離溝23の間隔(周期)はレーザダイオードの光共振器長の約700μmであり、溝は基板の端から端まで一直線に形成する。また、前記分離溝23の深さはサファイア基板の厚み範囲内において作製する。なお、サファイア基板の厚みは前記素子構造を形成した後、研削機を用いてトータル100μm程度の厚みになるように基板裏面を研磨する。次に、図2(b)に示すように、AlGaInN系レーザ構造結晶21側からパルスレーザビーム24を前記分離溝23に対応する位置に照射し、基板を完全に分離する。ただしレーザビーム照射は直接分離溝23まで貫通させなくても良く、AlGaInN系レーザ構造結晶21だけに照射した後、基板に力を加えて分離溝23に添って割っても良い。またパルスレーザビームのスキューは、集光レンズを移動させてビームを移動させても、ビームを固定し基板をステージ等に保持しこれを移動させても良い。図1は第1の実施例を示すAlGaInN系半導体レーザ構造を形成した基板1上においてパルスレーザビームを照射し、分離加工部2を形成した状態を表す図

(AlGaInN系結晶成長を施した側から見た図)である。なおパルスレーザビームは前記図1に示すようにレーザ共振器作製部分4近傍には照射せず、素子幅程度の周期で照射/非照射の部分形成することが望ましい。これは前記図2の工程で説明したようにAlGaInN系レーザバー3を作製する際に分離加工部2に添って力を加えれば、レーザを照射していない共振器作製部分4近傍も分離加工部2に添って容易に割ることができかつレーザ照射の影響を受けないので原子層オーダーで自然形成された共振器面が実現できる。なお、図1においてレーザビームを照射して形成する溝の方向は基板であるサファイアの<11-20>方向であるが、<1-100>方向であっても良い。更にレーザ照射を任意に

結晶軸方向に行っても問題ない。図4は前記方法を用いてパルスレーザビーム照射により形成した素子の共振器近傍における断面図である。レーザ照射はサファイアの $\langle 11-20 \rangle$ 方向に行う。サファイアM面43が精度良く形成されるので、AlGaInN系レーザの共振器面41（この場合A面）の平坦性が極めて良好に、かつ再現性良く形成される。

【0023】本発明において、照射するパルスレーザは例えばチタン・サファイア系のピーク波長が赤外付近で、パルス幅は数100fsの超短パルスを用いる。超短パルスレーザを用いることで照射するレーザの尖頭値パワーを短時間で著しく増大させることができ、短時間に得られた強いレーザパワーにより多光子吸収過程により原子の結合が切れ基板や結晶が分離切断される（レーザアブレーション）。これによりレーザビームを照射した領域において熱によるダメージを著しく低減させることが可能となる。

【0024】更に本発明において、パルスレーザビームを照射することにより、作製するレーザ素子の共振器近傍ぎりぎり（数 μm 程度）まで照射しても、前記共振器にダメージを与えることなく溝加工できる。従来、ダイヤモンドカッター等を用いて溝加工した場合、溝周辺部にひびや欠陥が入ってしまうために作製するレーザ素子の共振器から100 μm 程度離れた位置までしか溝加工できず、このためにレーザバーを作製する際に十分なガイドとなる溝が得られず、力を加えて割る際に途中で大きく外れて歩留まりを極端に低下させていたが、本発明により格段の歩留まり向上が実現できた。

【0025】なお本実施例においては基板としてサファイアを示したがAlGaInN系結晶のエピタキシャル成長に一般に用いる他のSi、SiC、Mg₂O₃、GaN、ガラス等についても有効であり、更にマスクを用いた選択横方向成長を行った低欠陥のAlGaInN系基板においても有効であることは言うまでも無い。

【0026】（実施例2）次にパルスレーザビームを基板の裏面に照射する工程について説明する。素子構造、基板厚み及びパルスレーザビーム照射に用いる光源は実施例1と同様である。

【0027】図3にパルスレーザビームを基板の裏面に照射し基盤を分離切断する工程を示す。図3（a）に示すように、サファイア基板32の裏面側にパルスレーザビーム照射33を施し分離溝34を周期的に形成する。前記分離溝34の間隔（周期）はレーザダイオードの光共振器長の約700 μm であり、溝は基板の端から端まで一直線に形成する。また、前記分離溝34の深さはサファイア基板の厚み範囲内において作製する。この時、基板の厚み方向にいて一部（10～20 μm 程度）はレーザ光のフォーカスを調整するなどしてパルスレーザ光によって基板が加工されないようにする。次に、図3

（b）に示すように、AlGaInN系レーザ構造結晶

31側からパルスレーザビーム35を前記分離溝34に対応する位置に照射し、分離溝36を形成する。パルスレーザビーム照射35のパターンは実施例1と同様図1に示す通り、作製するレーザ素子の共振器端面部には照射せずに周期的に行うものとする。最後に図3（c）に示すように図3（b）の状態に力を加え基板を割る。

【0028】本発明の工程によれば基板裏面側からパルスレーザビームを照射するので、基板厚み方向においてAlGaInN系レーザ構造結晶と基板との界面近傍ぎりぎりまで前記結晶部にダメージを与えることなく溝加工できるので、ダイヤモンドカッター等を用いた場合のように、溝加工部周辺に生じるクラックやひび割れを回避するために結晶と基板との界面から溝加工を離す必要がなく、格段に歩留まり良くレーザバーを作製できる。

【0029】本発明がサファイア以外の基板に用いても有効であることは実施例1と同様である。

【0030】（実施例3）図8（a）に示すようにサファイアC面基板81にフォトリソグラフィーやドライエッチングプロセス等を用いて溝加工82を施す。用いた基板の厚み及び全径はそれぞれ約400 μm 及び2インチである。溝加工はサファイアの $\langle 1-100 \rangle$ 及び $\langle 11-20 \rangle$ 方向に沿って直線上に施し、基板周辺部ほど溝と溝との間隔を密にする。典型的な溝と溝との間隔は、基板中心部は500～1000 μm 程度、基板周辺部は50～100 μm 程度で、溝幅は1～3 μm 程度で、溝深さは約5～100 μm 程度である。なお溝加工はパルスレーザビーム照射を行って作製してもよい。

【0031】前記加工基板を用いて図9に断面図を示すAlGaInN系レーザ構造を作製する。まずMOVPE法により前記図8（a）に示した溝加工を施した空隙902を有するサファイア基板901の主にC面上にGaNバッファ層を介してアンドープGaN層903、n-GaN層904、n-AlGaInクラッド層905、n-GaN光ガイド層906、Ga_{1-x}In_xN/Ga_{1-y}In_yN（ $0 < y < x < 1$ ）から成る多重量子井戸（MQW）活性層907、p-AlGaIn/GaN超格子キャップ層908、p-GaN光ガイド層909、p-AlGaIn/GaN超格子クラッド層910、p-GaN第二コンタクト層911、p-GaN第二コンタクト層912を順次結晶成長する。そしてp-GaN第二コンタクト層912上に幅3 μm 程度のリッジストライプが形成され、その両側はSiO₂914によって埋め込まれる。その後リッジストライプおよびSiO₂914上に例えばNi/Auから成るp電極913、また一部をn-GaN層904が露出するまでエッチングした表面に例えばTi/Alから成るn電極915が形成される。本素子においてn電極915を接地し、p電極913に電圧を印加すると、MQW活性層907に向かってp電極913側からホールが、またn電極915側から電子が注入され、前記MQW活性層907内で光学

利得を生じ、発振波長400nm帯のレーザ発振を起こす。

【0032】図8(a)に示すような変調周期を有した溝加工を施したサファイア基板を用いて前記素子構造を結晶成長すると以下に示すように基板の反りやクラックを低減するのに極めて大きな効果がある。すなわち、図7(b)に示すようにサファイア基板74に施した空隙76上ではAlGaInN系レーザ構造75が横方向成長し、結合部74でスムーズに結合するので素子表面の結晶平坦性は確保される。更に、基板周辺部においては溝加工の加工周期が基板中心部よりも短く、より密に空隙が存在するので、この領域においてはサファイア基板74とAlGaInN系レーザ構造75との間に生じる応力が緩和され、反りや変形更にはこれらによってもたらされる結晶部のクラックが著しく低減される。この結果、2インチ系の基板を用いて前記素子構造を結晶成長し、これにフォトリソグラフィ等を用いてレーザのリッジストライプを形成する際に、フォトマスクとの位置ずれ等がなくなるので、量産を行う際に極めて歩留まり良く生産できることがわかった。更に、実施例1や実施例2に示すようにレーザバーを作製する際にいても、本発明を用いて基板の反りや変形を無くすと著しく高歩留まりでレーザバーが作製できることが判明した。

【0033】サファイア基板の溝加工は、図8(b)に示すように基板周囲程より密につまった同心円状でも良い。この場合基板全体にわたりより歪みによる変形を抑制できる。更に図8(c)に示すように例えば<1-10>や<11-20>のように特定の方向のみに沿って溝加工を施せば、溝加工に垂直な方向の歪みが平行方向の歪みよりも緩和されるのでc面内において異方的な歪み応力を意図的に加えることが実現でき、歪みによってAlGaInN系結晶のバンド構造を変えレーザの発光特性改善が可能となる。

【0034】また溝加工の深さを基板周辺部ほど深くすることにより基板周辺部がより緩和されるので、前記深さ変調は周期変調の場合と同様に基板の反りや変形に対して有効である。

【0035】

【発明の効果】以上説明したように、本発明のAlGaInN系半導体の第一の製造方法によれば、基板上に構成された $\text{Al}_x\text{Ga}_y\text{In}_z\text{N}$ ($x+y+z=1$) 系結晶の結晶部及び基板部の内少なくともいずれかにパルスレーザビーム光を照射して分離溝を形成することにより、前記基板及びAlGaInN系結晶の結晶面に沿って忠実に溝加工が実現でき、極めて平坦性に優れた分離溝断面を作製することが可能である。

【0036】また、本発明のAlGaInN系半導体の第二の製造方法によれば、基板上に構成された $\text{Al}_x\text{Ga}_y\text{In}_z\text{N}$ ($x+y+z=1$) 系結晶の結晶部及び基板部の内少なくともいずれかにパルスレーザビーム光を照

射することにより素子分離を行うことにより、前記基板及びAlGaInN系結晶の結晶面に忠実に沿って素子分離が可能となり、この工程を半導体レーザに適用した場合極めて高歩留まりなレーザダイオード光共振器端面の作製が可能となる。

【0037】また、本発明のAlGaInN系半導体の第三の製造方法によれば、基板上に構成された $\text{Al}_x\text{Ga}_y\text{In}_z\text{N}$ ($x+y+z=1$) 系結晶の結晶部及び裏面基板部に分離溝を形成する工程と、前記分離溝の内少なくともいずれかにおいてパルスレーザビーム光を照射して前記分離溝を追加加工し、パルスレーザビーム光を照射して形成した分離溝に添ってへき開することにより、極めて平坦なレーザダイオード共振器面の作製が高歩留まりで可能となる。特に、前記パルスレーザビーム光照射による分離溝形成方法は多光子過程によるもので熱的な過程が支配的ではなく、レーザダイオードを構成する基板及び結晶を損傷することなく短時間に結晶を構成する原子の結合を切断できるので、信頼性に優れた発光素子が実現できる。

【0038】また、本発明のAlGaInN系半導体の第四の製造方法及び素子構造によれば、基板表面または裏面のうち少なくとも一方に周期または深さを基板内において変調させた溝加工を施した後、前記基板上にAlGaInN系半導体素子の作製を行うことにより、素子を構成する基板と前記AlGaInN系結晶との間に発生する熱歪みを低減でき、反り、変形及びクラック等の無い高品質な素子が実現できる。

【図面の簡単な説明】

【図1】AlGaInN系素子構造を形成した基板上におけるパルスレーザビーム照射による分離溝形成パターンを表す図

【図2】(a)パルスレーザビーム照射による分離溝形成の工程図

(b)パルスレーザビーム照射による分離溝形成の工程図

【図3】(a)パルスレーザビーム照射による分離溝形成の工程図

(b)パルスレーザビーム照射による分離溝形成の工程図

(c)パルスレーザビーム照射による分離溝形成の工程図

【図4】パルスレーザビーム照射により形成した素子断面図

【図5】(a)従来のスクライビング法により形成した素子断面図

(b)従来のスクライビング法により形成した分離溝形成パターンを表す図

【図6】本発明のプロセスを施したAlGaInN系素子構造を示す図

【図7】(a)従来法によるサファイア基板上AlGa

InN系素子断面図

(b) 本発明によるサファイア基板上AlGaInN系素子断面図

【図8】(a) 本発明による基板上への加工パターンを表す図

(b) 本発明による基板上への加工パターンを表す図

(c) 本発明による基板上への加工パターンを表す図

【図9】本発明による加工基板を用いたAlGaInN系素子断面図

【図10】従来法による加工基板を用いたAlGaInN系素子断面図

【図11】(a) 従来法によるマスク基板を用いたGaN結晶の構造断面図

(b) 従来法による加工基板を用いたGaN結晶の構造断面図

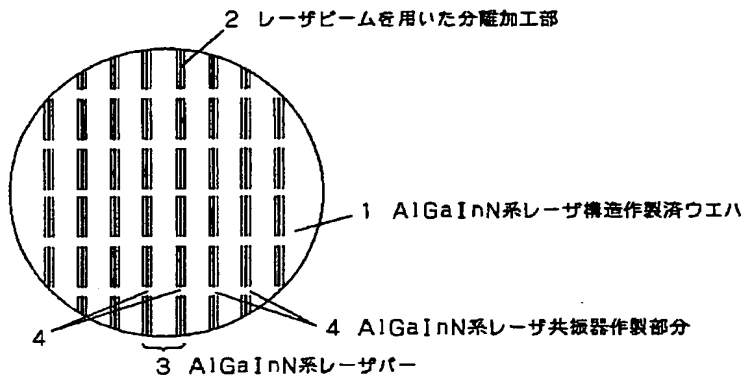
【符号の説明】

- | | |
|------------------------|--------------------------|
| 1 AlGaInN系レーザ構造作製済ウエハ | 83 サファイア基板 |
| 2 レーザビームを用いた分離加工部 | 84 溝加工 |
| 3 AlGaInN系レーザバー | 85 サファイア基板 |
| 4 AlGaInN系レーザ共振器作製部分 | 86 溝加工 |
| 21 AlGaInN系レーザ構造 | 601 サファイア基板 |
| 22 サファイア基板 | 602 バッファ層 |
| 23 分離溝 | 603 n-AlGaIn層 |
| 24 パルスレーザビーム照射 | 604 n-AlGaInクラッド層 |
| 25 分離溝 | 605 n-GaN光ガイド層 |
| 31 AlGaInN系レーザ構造 | 606 GaInN/GaN-MQW活性層 |
| 32 サファイア基板 | 607 p-GaN光ガイド層 |
| 33 パルスレーザビーム照射 | 608 p-AlGaInクラッド層 |
| 34 分離溝 | 609 p-GaNコンタクト層 |
| 35 パルスレーザビーム照射 | 610 p電極 |
| 36 分離溝 | 611 SiO ₂ |
| 41 AlGaInN系レーザ共振器面 | 612 n電極 |
| 42 サファイアC面 | 901 サファイア基板 |
| 43 サファイアM面 | 902 空隙 |
| 51 サファイアM面 | 903 u-GaN層 |
| 52 AlGaInN系レーザ結晶M面 | 904 n-GaN層 |
| 53 AlGaInN系レーザ結晶A面 | 905 n-AlGaInクラッド層 |
| 54 サファイアC面 | 906 n-GaN光ガイド層 |
| 55 AlGaInN系レーザ構造作製済ウエハ | 907 活性層 |
| 56 ダイヤモンドカッターを用いた分離溝 | 908 p-AlGaIn/GaN超格子キャップ層 |
| 57 分離溝周辺部のひび割れ及び傷 | 909 p-GaN光ガイド層 |
| 58 レーザ共振器作製部分 | 910 p-AlGaIn/GaN超格子クラッド層 |
| 71 サファイア基板 | 911 p-GaN第二コンタクト層 |
| 72 AlGaInN系レーザ構造 | 912 p-GaN第一コンタクト層 |
| 73 変形及び応力が大きい領域 | 913 p電極 |
| 74 結合部 | 914 SiO ₂ |
| 75 AlGaInN系レーザ構造 | 915 n電極 |
| 76 空隙 | 1001 サファイア基板 |
| 81 サファイア基板 | 1002 バッファ層 |
| 82 溝加工 | 1003 n-AlGaIn層 |
| | 1004 n-AlGaInクラッド層 |
| | 1005 n-GaN光ガイド層 |
| | 1006 GaInN/GaN-MQW活性層 |
| | 1007 p-GaN光ガイド層 |
| | 1008 p-AlGaInクラッド層 |
| | 1009 p-GaNコンタクト層 |
| | 1010 p電極 |
| | 1011 SiO ₂ |
| | 1012 n電極 |
| | 1101 サファイア基板 |
| | 1102 GaN |
| | 1103 SiO ₂ |
| | 1104 GaN層 |
| | 1105 転位の少ない領域 |
| | 1106 転位の多い領域 |
| | 1107 サファイア基板 |

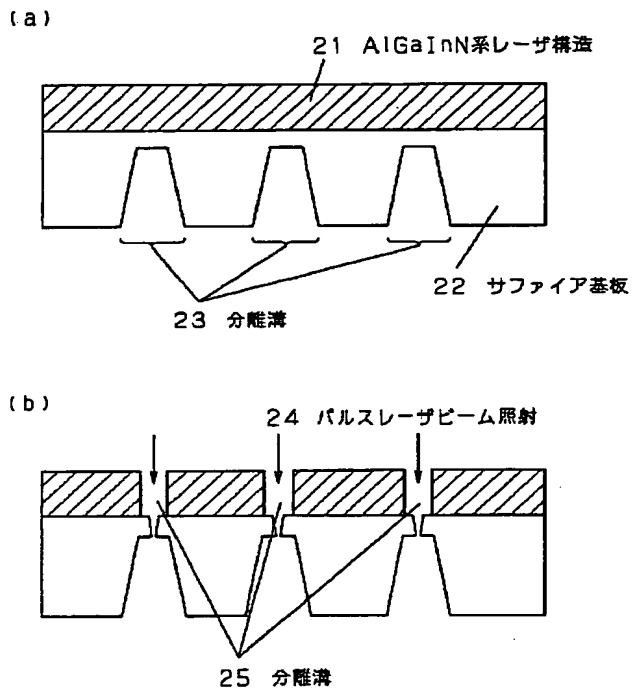
1108 GaN
1109 空隙

1110 転位の少ない領域
1111 転位の多い領域

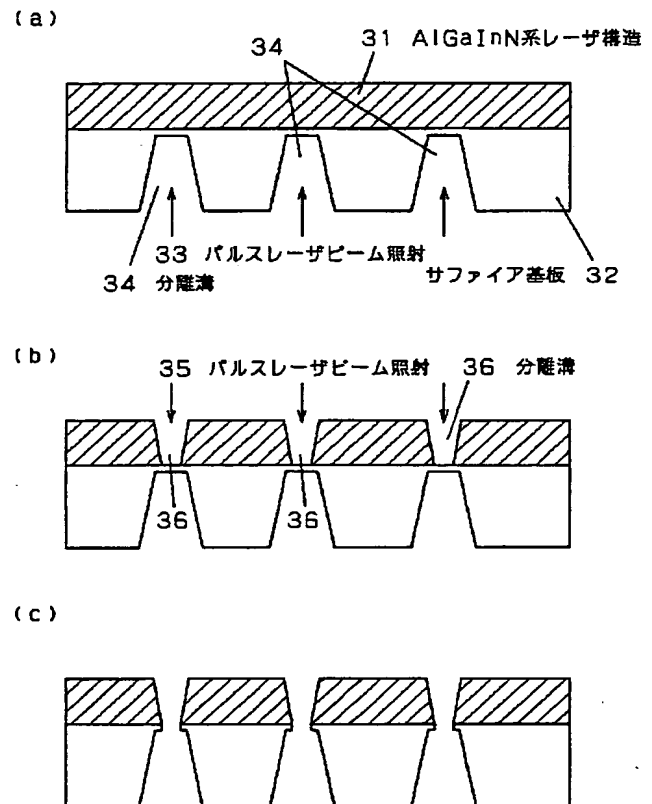
【図1】



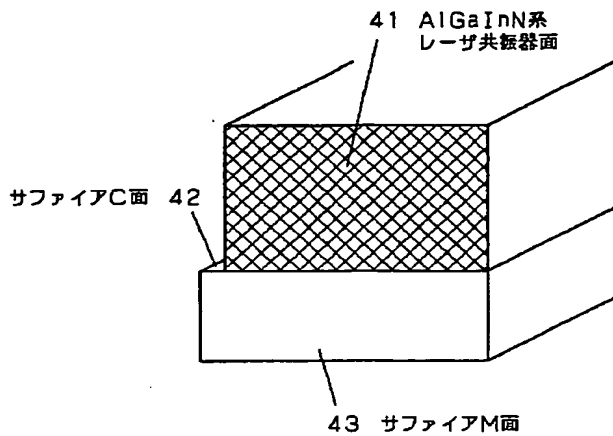
【図2】



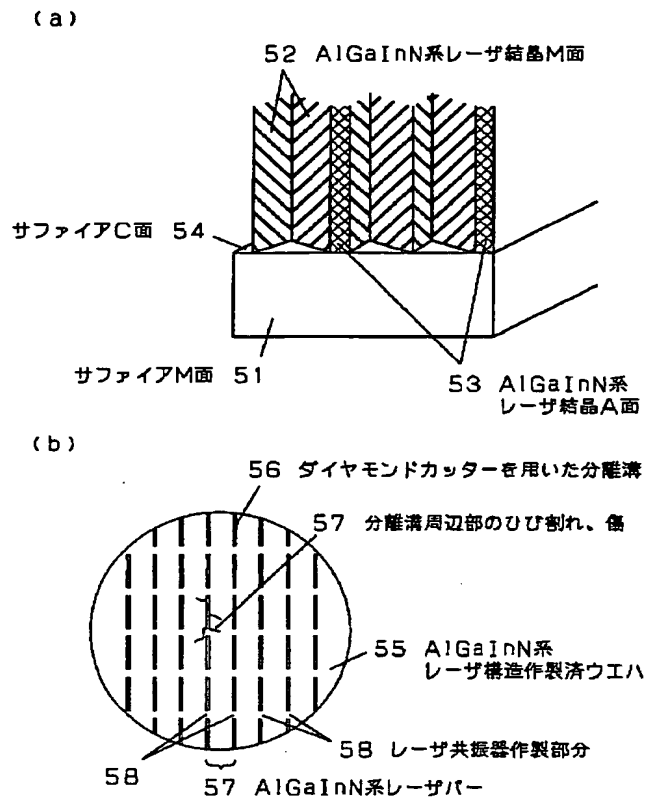
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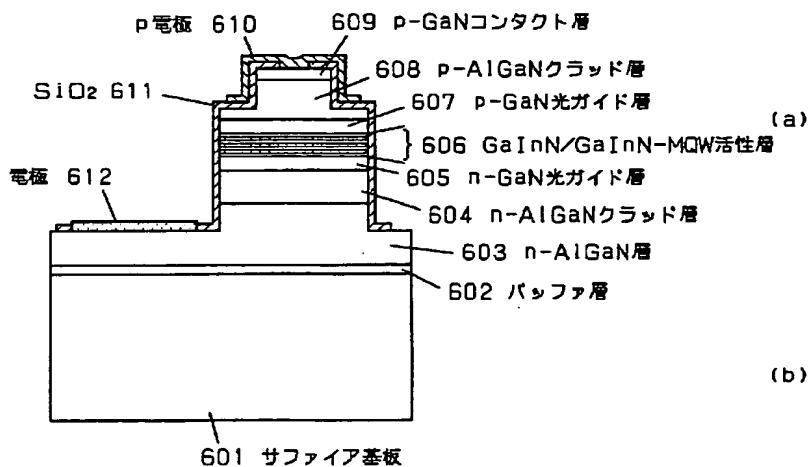
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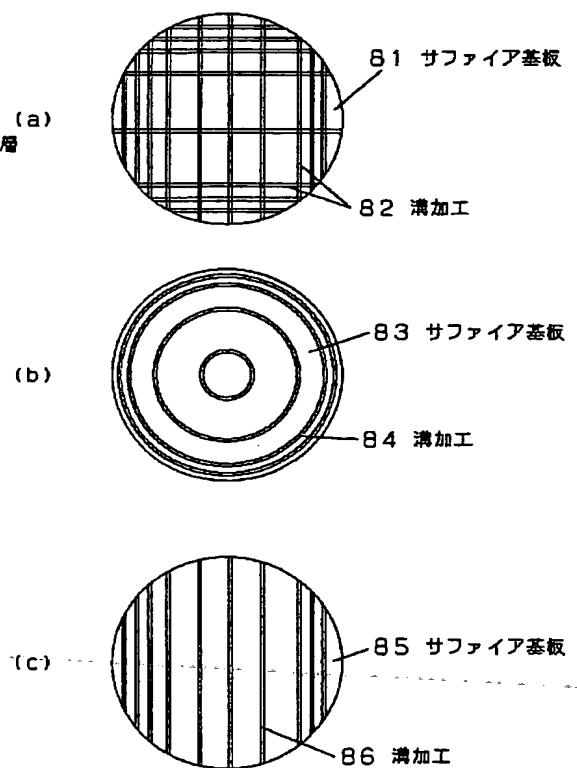
【図5】



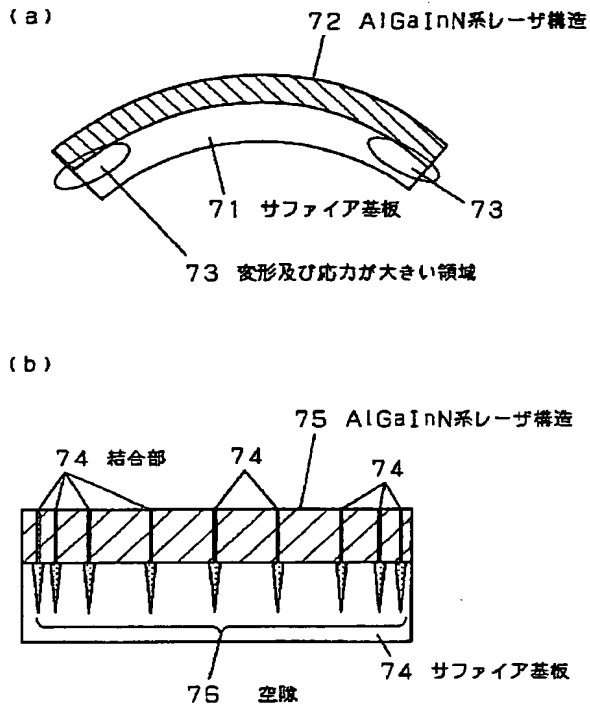
【図6】



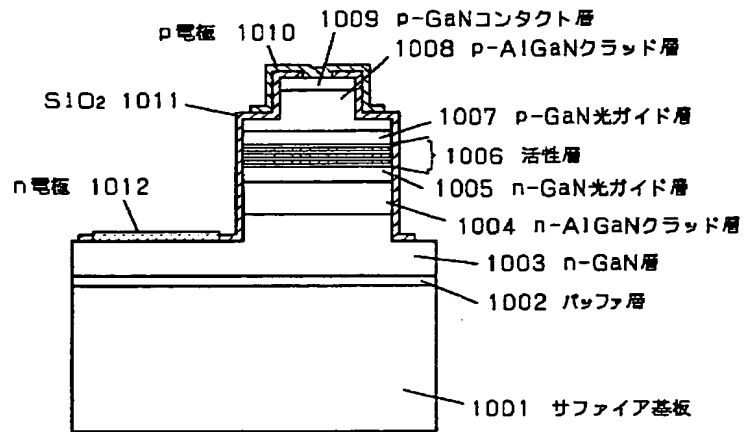
【図8】



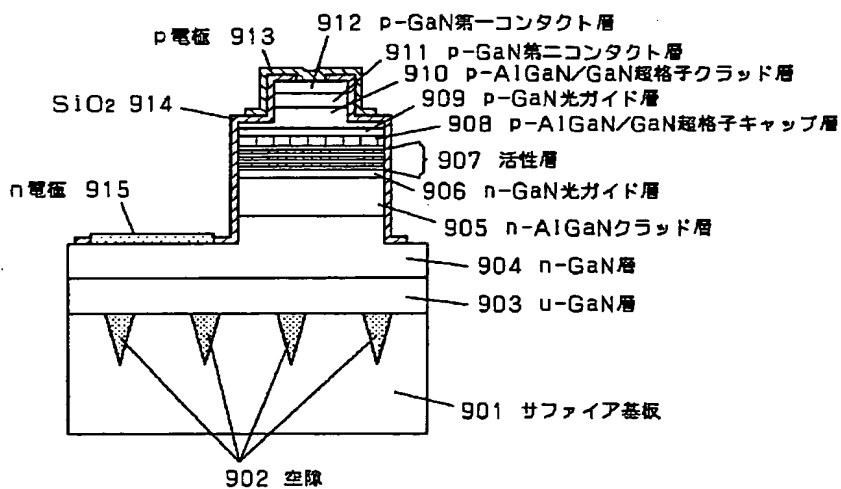
【図7】



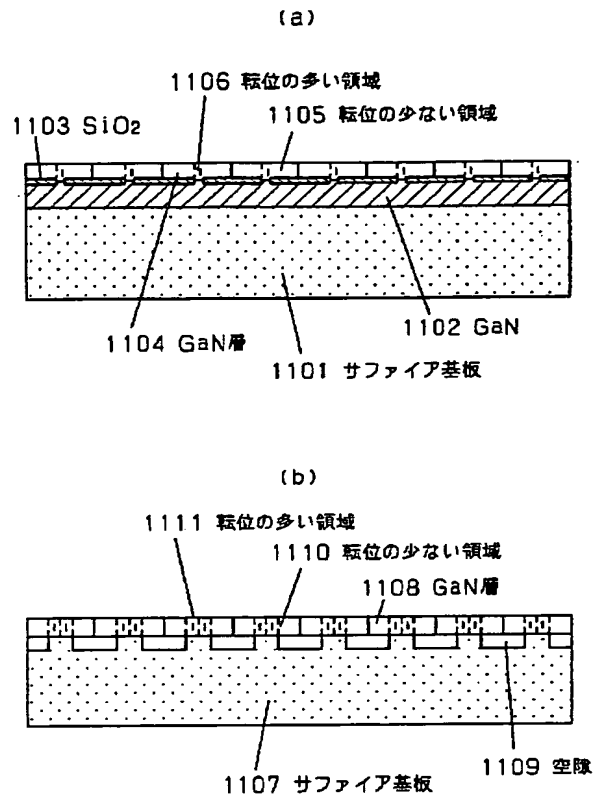
【図10】



【図9】



【図11】



フロントページの続き

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